800 J Of Heat Absorbed By 120 G Of Water At 25 C, What Is The Final Temperature At Equilibrium

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When a specific amount of heat is added to water, understanding how it affects the temperature of the substance is fundamental in thermodynamics. In this case, we analyze the scenario where 800 Joules (J) of heat energy are absorbed by 120 grams of water initially at 25°C. The key question is: what is the final temperature of the water once thermal equilibrium is reached? This article provides a comprehensive explanation of the principles involved, including necessary calculations, relevant formulas, and factors influencing the temperature change.

Understanding Heat Transfer and Specific Heat Capacity

What is Heat Transfer?

Heat transfer is the process of thermal energy moving from a hotter object or substance to a cooler one, driven by temperature differences. When water absorbs heat, its internal energy increases, leading to a rise in temperature until equilibrium is established.

Role of Specific Heat Capacity

The specific heat capacity (usually denoted as c) of a substance indicates the amount of heat required to raise the temperature of one gram of the substance by one degree Celsius (or Kelvin). For water, the specific heat capacity is well established:

- Specific heat capacity of water: 4.186 J/g°C

This value is crucial in calculating the temperature change resulting from heat absorption.

Calculating the Final Temperature of Water After Heat Absorption

Fundamental Formula

The basic relationship connecting heat transfer, mass, specific heat, and temperature change is:

$$
Q = mc\Delta T
$$

Where:
- Q = heat energy absorbed or released (in Joules)
- m = mass of the substance (in grams)
- c = specific heat capacity (J/g°C)
- ΔT = change in temperature (°C)

Rearranged to find the change in temperature:

$$
\Delta T = \frac{Q}{mc}
$$

The final temperature (T_f) can then be computed as:

$$
T_f = T_i + \Delta T
$$

Where:
- T_i = initial temperature (°C)
- T_f = final temperature (°C)

Step-by-Step Calculation

Given Data

- Heat energy absorbed: $Q = 800\, \text{J}$
- Mass of water: $m = 120\, \text{g}$
- Initial temperature: $T_i = 25\, °C$
- Specific heat capacity of water: $c = 4.186\, \text{J/g°C}$

Calculate Temperature Change (ΔT)

Applying the formula:

$$
\Delta T = \frac{Q}{mc} = \frac{800\, \text{J}}{120\, \text{g} \times 4.186\, \text{J/g°C}}
$$

Calculating denominator:

$$
120 \times 4.186 = 502.32\, \text{J/°C}
$$

Now, computing ΔT:

$$
\Delta T = \frac{800}{502.32} \approx 1.593\, °C
$$

Result: The water's temperature increases by approximately 1.593°C.

Determine Final Temperature (T_f)

Adding the temperature change to the initial temperature:

$$
T_f = 25\, °C + 1.593\, °C \approx 26.593\, °C
$$

Final Temperature: The water reaches approximately 26.59°C after absorbing 800 J of heat.

Additional Considerations and Real-World Factors

While the calculation above provides a precise estimate based on ideal conditions, several real-world factors could influence the final temperature:

1. Heat Losses

In practical scenarios, some heat may escape to the surroundings due to conduction, convection, or radiation, leading to a slightly lower final temperature than calculated.

2. Temperature Measurement Accuracy

Precise measurements require calibrated thermometers and controlled environments to minimize errors.

3. Phase Changes

If the temperature approaches water's boiling point (100°C at standard pressure), phase changes such as boiling could occur, absorbing additional heat without raising temperature further.

4. Specific Heat Capacity Variability

While 4.186 J/g°C is standard for water, minor deviations can occur based on temperature and impurities.

Applications of Heat Calculations in Daily Life and Industry

Understanding how to calculate changes in temperature based on heat transfer is essential in various fields:

1. **Cooking:** Estimating how much heat is needed to raise the temperature of water or other liquids.

2. **Engineering:** Designing heating systems, such as boilers or radiators, to achieve desired temperature levels efficiently.

3. **Environmental Science:** Modeling climate phenomena involving heat exchange in water bodies.

4. **Medical Applications:** Managing thermal therapies where precise temperature control is critical.

Summary and Key Takeaways

- When 800 J of heat is absorbed by 120 g of water initially at 25°C, the water's temperature increases by approximately 1.593°C.
- The final temperature of the water at thermal equilibrium is about 26.59°C.
- The calculation relies on the fundamental heat transfer formula $Q = mc\Delta T$, emphasizing the importance of specific heat capacity.
- Real-world factors like heat loss and phase changes can influence the actual final temperature, so these calculations provide an ideal estimate.
- Mastery of these concepts is vital in fields ranging from cooking to engineering and environmental science.

Conclusion

Understanding how heat absorption affects water temperature is essential for practical applications and scientific analyses. The ability to accurately calculate temperature changes from known heat input, mass, and specific heat capacity is a foundational skill in thermodynamics. In this scenario, the absorption of 800 J leads to a modest temperature increase, illustrating how energy transfer translates into thermal changes. Whether in laboratory experiments, industrial processes, or everyday life, these principles underpin effective thermal management and energy efficiency.

Keywords: heat transfer, specific heat capacity, water temperature calculation, thermodynamics, energy absorption, thermal equilibrium, heat capacity of water, temperature change, Joules, grams, Celsius

Frequently Asked Questions

What is the formula to calculate the temperature change when a certain amount of heat is absorbed by water?

The temperature change (ΔT) can be calculated using the formula $Q = mc\Delta T$, where Q is the heat absorbed, m is the mass, and c is the specific heat capacity of water.

Given 800 J of heat absorbed by 120 g of water

initially at 25°C, what is the final temperature of the water?

First, convert mass to kg: 120 g = 0.12 kg. Using $Q = mc\Delta T$: $\Delta T = Q / (mc) = 800\ J / (0.12\ kg \times 4184\ J/kg°C) \approx 1.6°C$. Final temperature = $25°C + 1.6°C \approx 26.6°C$.

What is the specific heat capacity of water used in calculations?

The specific heat capacity of water is approximately 4184 J/kg°C.

How does the initial temperature of water affect the final temperature after heat absorption?

The initial temperature sets the starting point; the final temperature is the initial temperature plus the temperature increase caused by the absorbed heat, assuming no heat loss.

What assumptions are made when calculating the final temperature of water after heat absorption?

Assumptions include no heat loss to surroundings, uniform temperature distribution, and constant specific heat capacity over the temperature range.

Can the heat capacity of water change significantly over small temperature ranges like this?

No, for small temperature changes such as 1-2°C, the specific heat capacity of water is considered constant.

What is the significance of knowing the heat absorbed in thermal physics?

Knowing the heat absorbed helps determine temperature changes, energy requirements, and thermal behavior of materials, essential for thermal management and engineering applications.

If the water reaches a final temperature of approximately 26.6°C, how much more heat would be needed to raise it to 30°C?

Using $Q = mc\Delta T$: $\Delta T = 30°C - 26.6°C = 3.4°C$. $Q = 0.12\ kg \times 4184\ J/kg°C \times 3.4°C \approx 1704\ J$.

Additional Resources

800 J Of Heat Absorbed By 120 G Of Water At 25°C, What Is The Final Temperature At Equilibrium

Understanding the relationship between heat transfer and temperature change is fundamental in thermodynamics. When a specific amount of heat is added to a substance like water, the temperature of that substance changes accordingly until it reaches a new equilibrium state. In this article, we delve into a practical example: calculating the final temperature of water after absorbing a known quantity of heat. This scenario exemplifies core principles of heat transfer, specific heat capacity, and thermal equilibrium—concepts crucial not only in scientific research but also in everyday applications ranging from climate control systems to cooking processes.

Background: The Basics of Heat Transfer and Specific Heat Capacity

Before tackling the specific problem, it's essential to grasp some foundational concepts that underpin the calculation.

What Is Heat? And How Is It Measured?

Heat refers to the transfer of thermal energy between systems due to temperature differences. It is measured in joules (J) in the International System of Units. When heat is added to a substance, it can cause a change in temperature, phase transition, or both, depending on the amount of heat and the properties of the substance.

Specific Heat Capacity: The Key Property

The specific heat capacity (often simply called specific heat) of a substance indicates how much heat energy is required to raise the temperature of one gram of that substance by one degree Celsius (or Kelvin). For water, the specific heat capacity is well-established:

- cwater ≈ 4.18 J/g°C

This value means that to increase the temperature of 1 gram of water by 1°C, approximately 4.18 joules of energy are needed.

The Problem Statement: Analyzing the Heat Absorption of Water

Let's restate the problem in detail:

- An initial mass of water, 120 grams, starts at an initial temperature of 25°C.
- The water absorbs a total of 800 joules of heat energy.
- The question is: What is the final temperature of the water at equilibrium after absorbing this heat?

This is a classic thermodynamics problem involving heat transfer and temperature change. By understanding how much heat is required to raise the water's temperature, we can determine its final temperature after the heat input.

Step-by-Step Solution: Calculating the Final Temperature

To solve this problem, we need to relate the heat added to the temperature change of the water using the fundamental heat transfer equation:

$$ Q = mc\Delta T $$

Where:

- Q is the heat absorbed or released (in joules),
- m is the mass of the substance (in grams),
- c is the specific heat capacity (J/g°C),
- ΔT is the change in temperature (final temperature minus initial temperature).

Rearranged to solve for the final temperature:

$$ T_{final} = T_{initial} + \frac{Q}{mc} $$

Let's identify the known variables:

- Q = 800 J
- m = 120 g
- c = 4.18 J/g°C
- Tinitial = 25°C

Calculating ΔT:

$$ \Delta T = \frac{Q}{mc} = \frac{800}{120 \times 4.18} $$

Calculating the denominator:

$$ 120 \times 4.18 = 501.6 $$

Thus:

$$ \Delta T = \frac{800}{501.6} \approx 1.595 \,^\circ\mathrm{C} $$

Determining the final temperature:

$$ T_{final} = 25^\circ\mathrm{C} + 1.595^\circ\mathrm{C} \approx 26.595^\circ\mathrm{C} $$

Result:

The water's temperature at equilibrium after absorbing 800 joules of heat will be approximately 26.6°C.

Implications and Real-World Applications

This straightforward calculation demonstrates how heat transfer affects temperature in practical scenarios. In the real world, such calculations are essential in various fields:

- Climate Science: Understanding temperature changes in bodies of water due to heat absorption.
- Engineering: Designing cooling systems, such as radiators or heat exchangers.
- Food Industry: Controlling cooking temperatures by precise heat application.
- Environmental Sciences: Predicting temperature fluctuations in natural water bodies resulting from heat inputs.

Furthermore, this example underscores the importance of knowing a substance's specific heat capacity, which varies among materials. For instance, metals typically have much lower specific heats than water, meaning they heat up and cool down faster.

Additional Considerations in Heat Transfer

Calculations

While the calculation above assumes an ideal scenario, real-world situations often involve additional factors:

- Heat Losses: In practice, some heat may be lost to the surroundings via conduction, convection, or radiation, leading to a different final temperature.
- Phase Changes: If the heat added is sufficient to reach water's boiling point (100°C at standard pressure), phase changes (liquid to vapor) occur, requiring additional heat (latent heat).
- Non-Uniform Heating: Heat may not be distributed evenly, leading to temperature gradients.

Understanding these factors is critical when designing experiments or industrial processes to ensure accurate predictions of temperature changes.

Conclusion: From Heat Transfer to Temperature Prediction

The analysis of 800 joules of heat absorbed by 120 grams of water initially at 25°C reveals a predictable and manageable temperature increase of approximately 1.6°C. This calculation exemplifies the practical application of fundamental thermodynamic principles, particularly the relationship encapsulated by \(Q = mc\Delta T\). Whether in lab settings, environmental studies, or engineering designs, mastering such calculations helps in predicting thermal behaviors, optimizing processes, and understanding the intricate dance of heat and matter in our universe.

In summary, when a known amount of heat is transferred to water, its temperature rises proportionally to the heat absorbed, provided no phase change occurs. Recognizing the significance of specific heat capacity and the precise measurement of heat transfer allows scientists and engineers to predict and manipulate thermal systems effectively, ensuring safety, efficiency, and accuracy in countless applications.

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